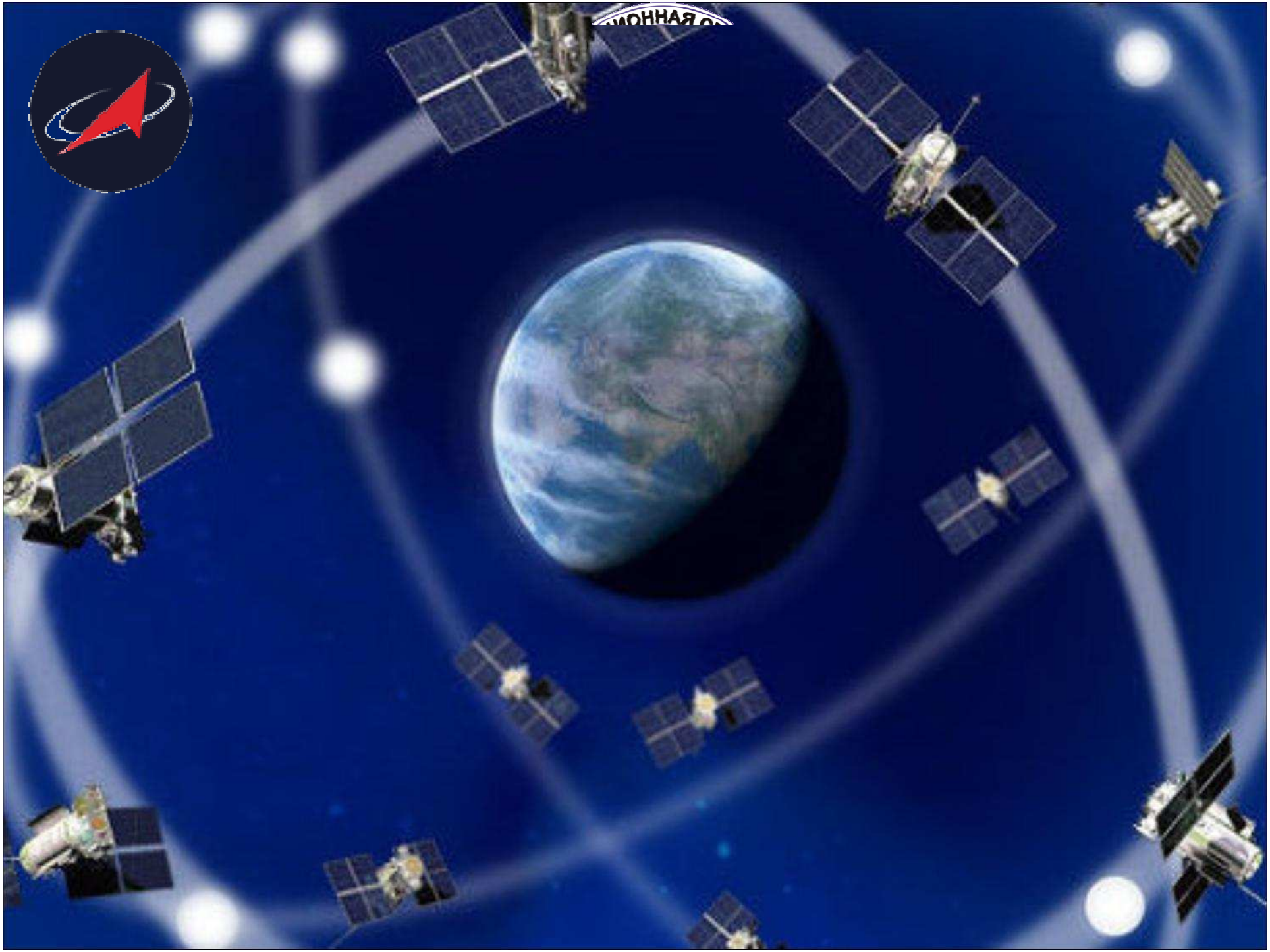


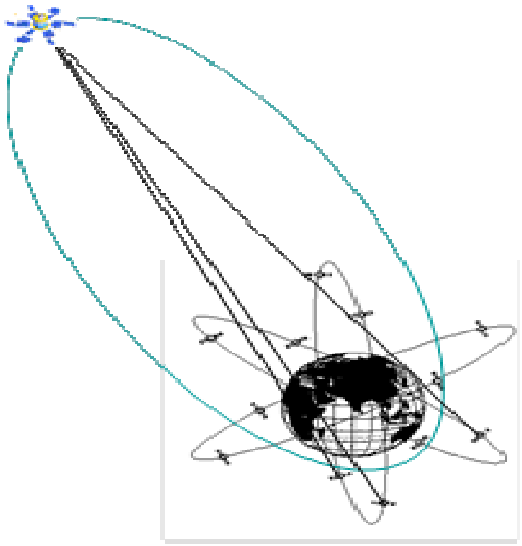
Objectives of GNSS application for the high orbit spacecraft navigation

High orbit spacecrafts are the spacecrafts in geostationary and high elliptical orbits (GEO and HEO)

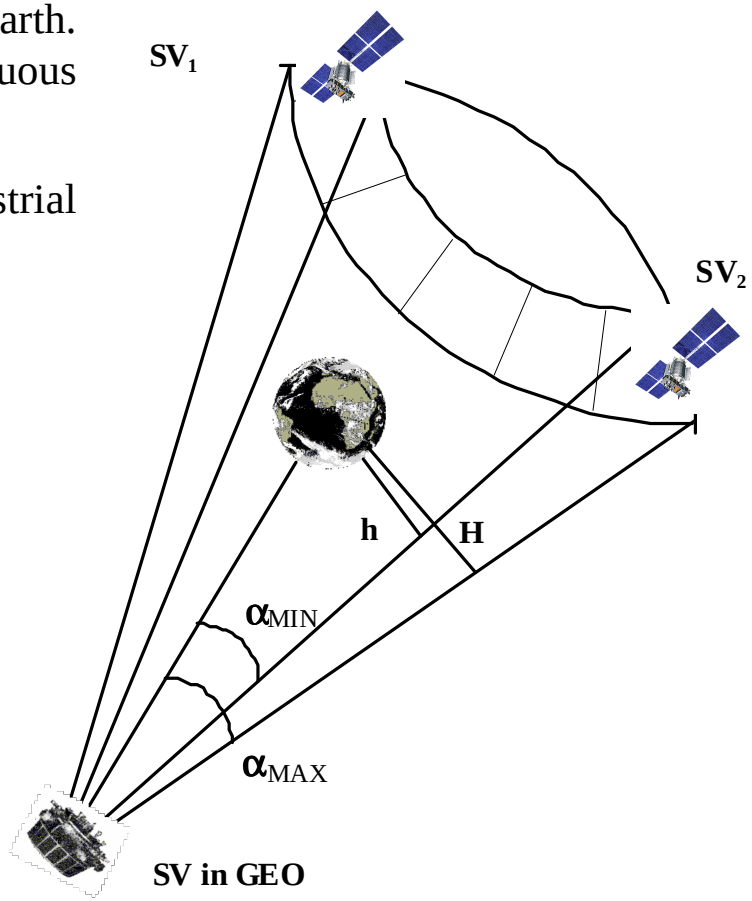
- High-precision spacecraft orbit determination to provide the corresponding communication link, monitoring and keeping in unattended mode the GEO satellite within an orbital slot with a required accuracy of ±0.1° (±0.05°)
- To reduce the load on ground control segment and to decrease its cost
- Reliability enhancement of the satellite orbit control system by reducing the influence of human factors

Navigation features of high orbit spacecrafts using GNSS signals

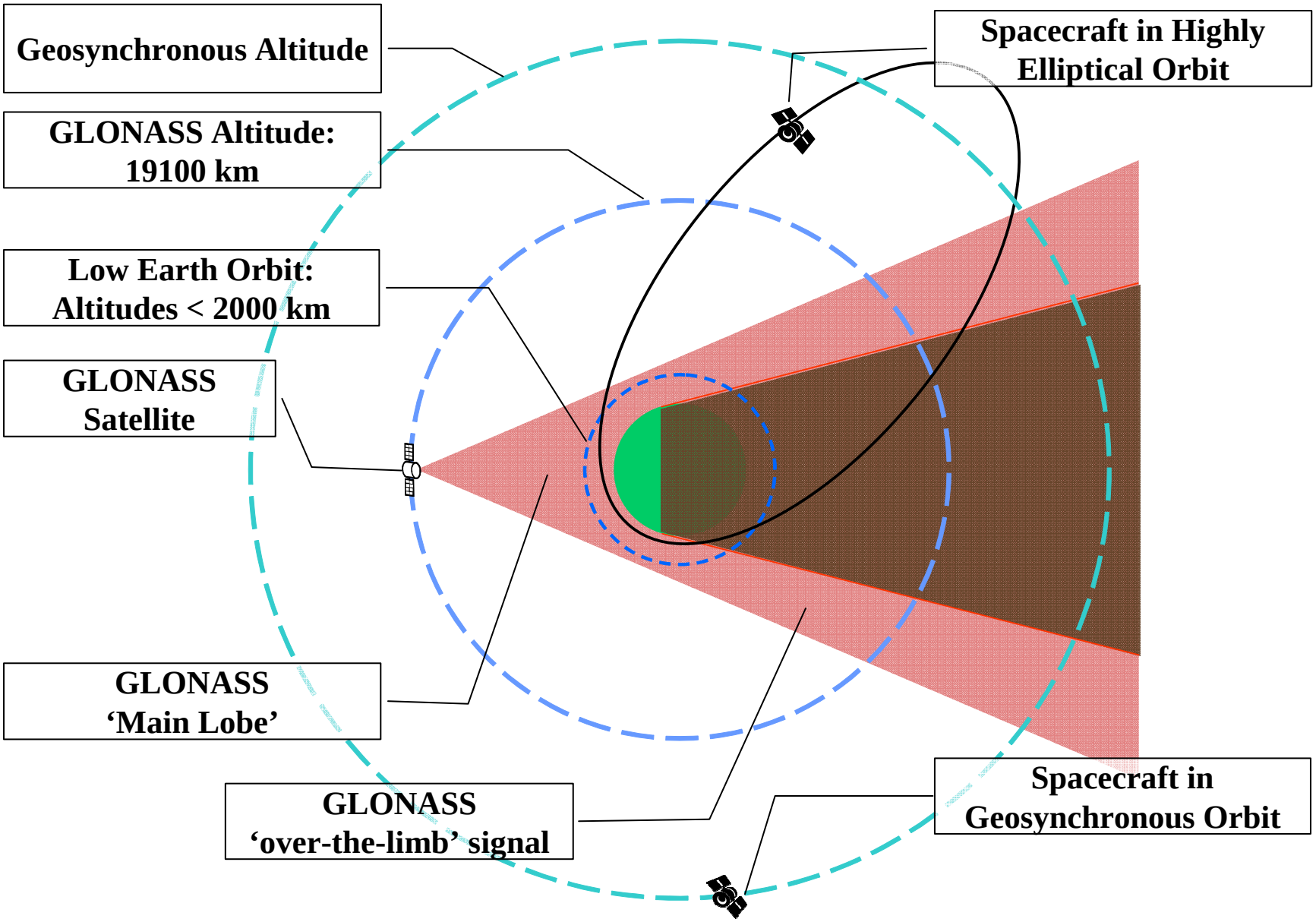
- The GNSS signals coverage in GEO is discontinuous. Geometrically, it looks like a set of intersecting annular bands formed by navigational signals transmitted from the other side of the Earth. The GNSS signals coverage in HEO is continuous only near the perigee.
- Traditional methods for positioning of a terrestrial user are not applicable.



SV in HEO



GLONASS SPACE SERVICE VOLUME



GLONASS SPACE SERVICE VOLUME

Definitions	Notes
Lower Space Service Volume (also known as 'MEO altitudes'): 3000 to 8000 km altitude	Four GLONASS signals available simultaneously a majority of the time but GLONASS signals over the limb of the Earth become increasingly important. One-meter orbit accuracies are feasible (post processed).
Upper Space Service Volume (GEO and HEO with the exception of the perigee area): 8000 to 36000 km altitude	Nearly all GLONASS signals received over the limb of the Earth. Accuracies ranging from 20 to 200 meters are feasible (post-processed) depending on receiver sensitivity and local oscillator stability.

GLONASS SPACE SERVICE VOLUME

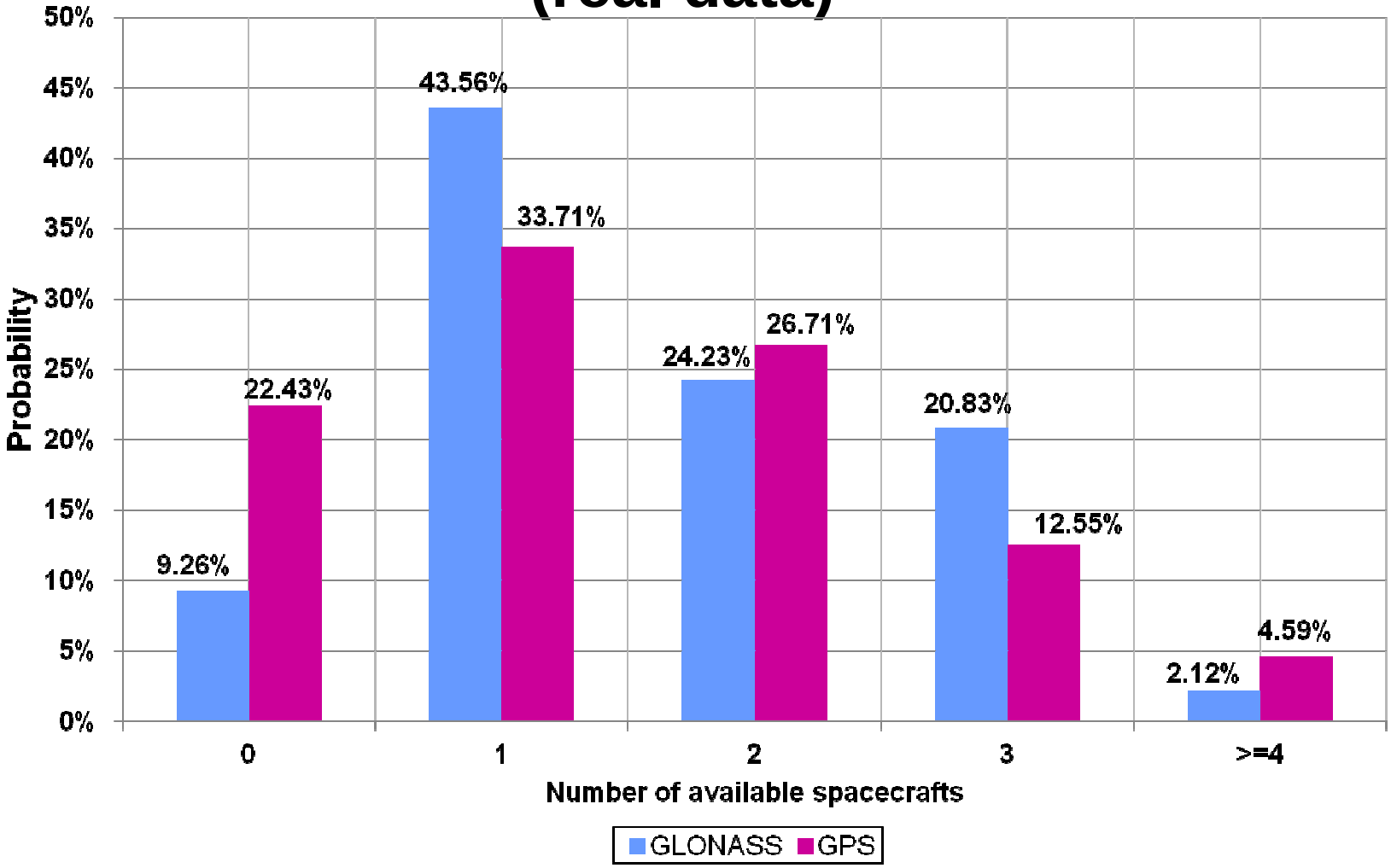
Parameters	Value	
User range error	1.4 meters	
Minimum Received Civilian Signal Power (GEO)	**With account of the GLONASS satellite's transmitter antenna gain pattern**	**Reference Off-Boresite Angle**
L1[1,2]	-180 ÷ -185 dBW	14 – 20 deg
L2	-177 ÷ -184.4 dBW	14 – 28 deg
L3	-176 ÷ -184 dBW	14 – 28 deg
Signal availability[3]		
MEO at 8000 km	**At least 1 signal**	**4 or more signals**
L1	81%	64%
L2, L3	100%	66%
Upper Space Service Volume (HEO/GEO)	**At least 1 signal**	**4 or more signals**
L1	70%	2.7%
L2, L3	100%	29%

Note 1 – FDMA signals in L1 and L2 bands and CDMA signals in L3

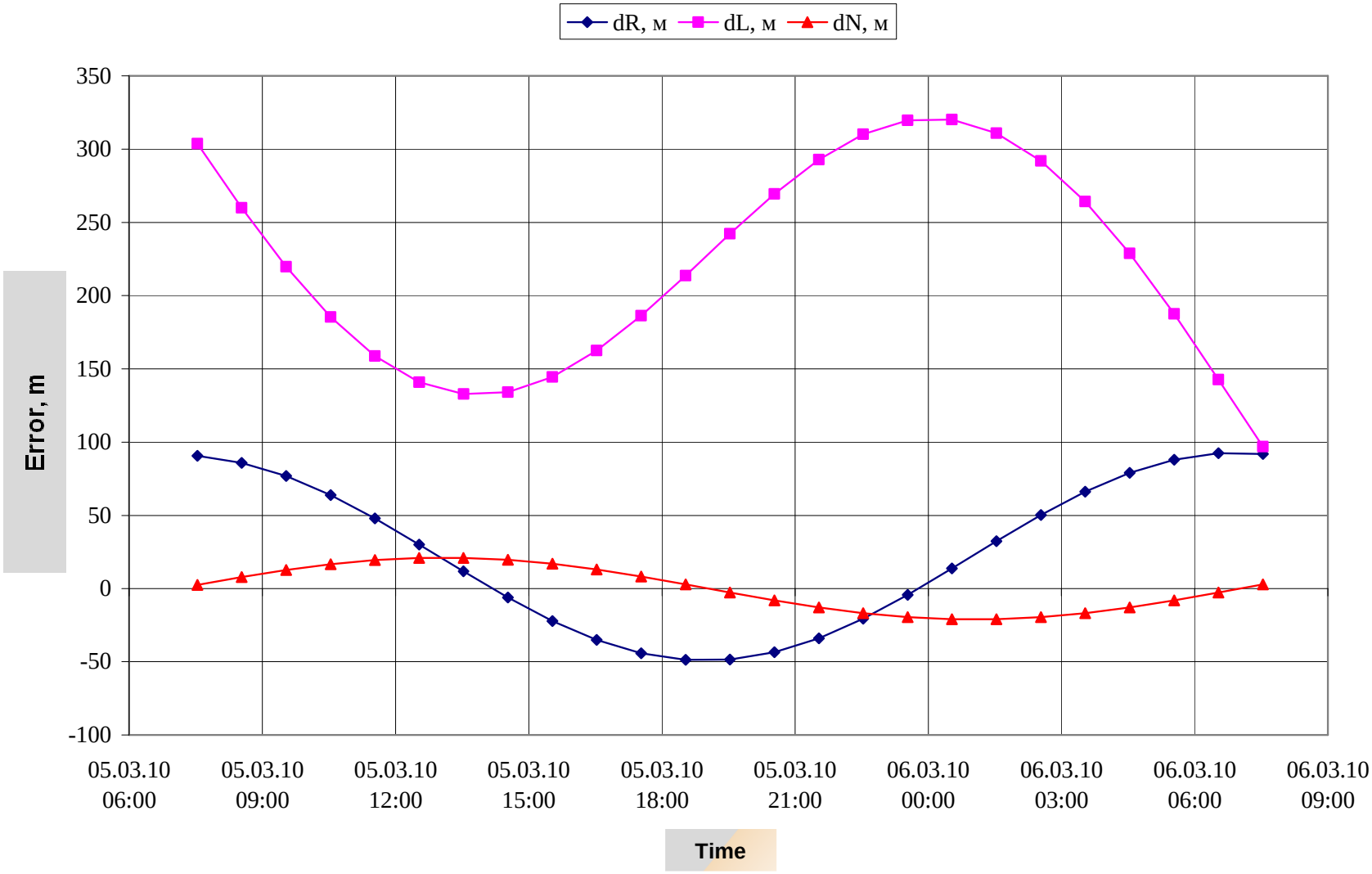
Note 2 – L1, L2 signals are transmitted by GLONASS-M and GLONASS-K satellites. At present, the L3 signal is transmitted by the GLONASS-K satellite. Furthermore, the final 7 GLONASS-M satellites will also transmit L3 signal (starting with the GLONASS-M No. 55 satellite).

Note 3 – Assumes that the high-orbit SV has at least one GLONASS satellite in view.

Availability of GLONASS and GPS spacecrafts in GEO (real data)



GEO satellite's positioning accuracy (orbit is determined using GLONASS and GPS measurements)



Experience in the application of GLONASS and GPS for the GEO spacecraft navigation

- The radionavigation equipment (RNE) has been used successfully on board geostationary spacecraft since 2008
- The possibility of reception and measurement of GLONASS/GPS signals as well as the possibility of positioning in GEO is confirmed
- Orbit accuracies ranging from 20 to 200 m are feasible *(a posteriori data)*
- The possibility of keeping of a geostationary spacecraft in an orbital slot with a required accuracy (±0,05°) is realized without ground control segment
- The Elektro-L meteorological satellite which will be launched in 2013 is equipped with RNE

Application of GLONASS and GPS for the HEO spacecraft navigation

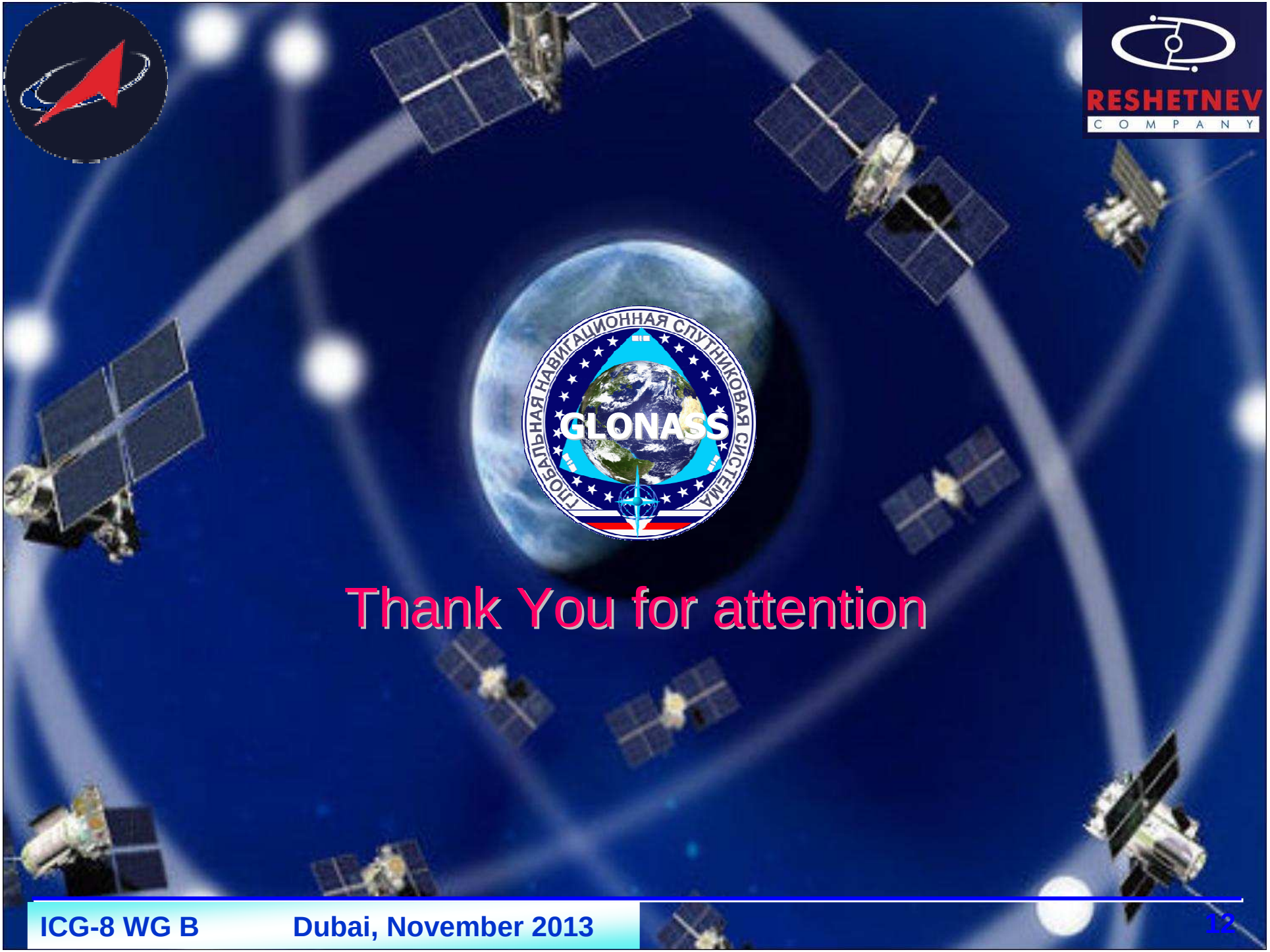
- Radionavigation equipment for spacecrafts in a Molniya orbit is developed
- Two antennas are mounted onboard: the first one is directed towards the Earth for activity near apogee, the another one is oriented in the opposite direction for activity near perigee
- Orbit accuracies ranging from 200 to 300 m are feasible *(a priori data)*

Possible GNSS development to improve the high orbit spacecraft navigation

- ***Supplementary antenna installation to transmit navigational signals in the opposite direction***

- ***The HEO and GEO spacecraft navigation accuracy can be increased up to 30 m if a navigational signal in the opposite direction is transmitted***

- ***A stable navigation on the Earth-Moon line with accuracies ranging from 250 to 2500 m will become possible with a navigational signal in the opposite direction***


ГЛОБАЛЬНАЯ НАВИГАЦИОННАЯ СПУТНИКОВАЯ СИСТЕМА
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Thank You for attention